The Relationship Between Beauty and Science

An Honors Thesis (HONRS 499)

by

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Purpose of Thesis

This paper is a discussion of the relationship between the philosophical idea of beauty and the process of formulating scientific theories. In this paper, various philosophers and scientists will describe beauty as an essential part of the process of creating scientific theories. Understanding the relationship between beauty and the sciences leads to a better understanding of the ultimate goal of the sciences, which is the quest for the laws of nature. This quest is lead, as Plato says all things are lead, by a sense of beauty.

The concept of beauty has intrigued philosophers for many years. Questions like "What exactly is Beauty?", "What makes a thing beautiful?", and "How is beauty tied to our emotions?" have all received various and very different answers. This philosophical concept with varying definitions seems a sharp contrast to the exacting world of the sciences. In reality, however, the two are intertwined. In fact, as this paper will point out, the world of physics, mathematics, etc. needs the idea of beauty to flourish, and really to even exist. After getting a little background on the concept of beauty and hearing what noted philosophers and scientists alike have to say on the subject of science and beauty, it will be obvious that the concept of beauty plays a significant, if not vital role in developing scientific theories.

The concept of beauty has come to mean many things to many people. It rarely is defined the same by any two people. Just as with something such as morality, there are no guidelines that say what is and is not beautiful. David Hume represents this by saying that beauty exists in things in the mind that contemplates it, or in more popular terms, beauty is in the eye of the beholder. Kant says that there are no reasons or principles which signify that a dress, house, or a flower is beautiful, but we say that these things are beautiful and that they should be called beautiful by others. He defines beauty by saying that the "beautiful" is that which, apart from a concept

pleases universally or is cognized as an object of a necessary delight. He further breaks beauty down into two forms: free beauty and beauty which is merely dependent. Free beauty is like a flower in nature. We can tell just by looking at it that it is beautiful, we need no other knowledge about it. But the beauty of a man or a machine or a building is based on the concept of the "end" or purpose, which defines what each is supposed to be. Plato further describes beauty in the Phaedrus by saying that it is an emotion felt by the soul. He says that the soul is awestricken and shudders at the sight of the beautiful, because it feels that something is evoked in it that was not imparted to it from the outside by the senses, but has always been already laid down there in the deeply unconscious region. It is thus more than merely a relative or subjective feeling; it is an absolute which exists as an innate idea.

The one thing that sticks with the idea of beauty no matter who tries to describe or define it is the fact that there is nothing that has to be or cannot be beautiful on the basis of some criteria. What this means is that the idea of beauty can be incorporated into anything, and in fact is incorporated into things which normally would not be thought of in those terms, such as the sciences. Steven Weinberg, a Nobel laureate in physics, says that physicists are motivated and, to some extent, governed by a sense of beauty. Einstein often referred to his work in these terms. With regard to his general theory of

relativity, he said that the part of it that had to do specifically with gravity was beautiful. It was as if it were made of marble. But the other side of the equation, which had to do with matter and how matter produces gravity was ugly. It was as if it were made of wood. In fact, he spent the last 30 years of his life trying, as Augustus did in Rome, to rebuild the right side of his equation so that it would be made of marble.

Along with Einstein, another advocate of the role of beauty as a governing force in the work of physicists is Paul Adrien Maurice Dirac. He was one of the cofounders of quantum mechanics and the originator of the idea of anti-matter. Dirac has been quoted as saying that he did not think students should pay too much attention to what the equations meant, but should only concern themselves with the beauty of the equations. He has also stated that it is more important to have beauty in one's equations than to have them fit experiments. J.W.N. Sullivan echos Dirac's remarks and relates them to science as a whole, not just physics. He states that since the primary object of the scientific theory is to express the harmonies which are found to exist in nature, we see at once that these theories must have an aesthetic value. The measure of the success of a scientific theory is, in fact, a measure of its aesthetic value, since it is a measure of the extent to which it has introduced harmony in what was before chaos. He goes on to say that it is in aesthetic value that the justification of

the scientific theory is to be found, and with it the justification of the scientific method. Since facts without laws would be of no interest, and laws without theories would have, at most, only a practical utility, we see that the motives which guide the scientific man are, from the beginning, manifestations of the aesthetic impulse.

Others have also seen this relationship between the concept of beauty and the sciences. For example, Chandrasekhar stated that In his entire scientific life, extending over forty-five years, the most shattering experience has been the realization that an exact solution of Einstein's equations of general relativity, discovered by the New Zealand mathematician, Roy Kerr, provides the absolute exact representation of untold numbers of massive black holes that populate the universe. This "shuddering before the beautiful," this incredible fact that a discovery motivated by a search after the beautiful in mathematics should find its exact replica in nature, persuaded him to say that beauty is that to which the human mind responds at its deepest and most profound.

Poincare also saw the relationship between beauty and the sciences, and he commented on the necessity of that relationship. He says that the scientist does not study nature because it is useful to do so. He studies it because he takes pleasure in it: and he takes pleasure in it because it is beautiful. He goes on to say that if nature were not beautiful, it would not be worth knowing and life would not

be worth living. Herman Weyl did not contemplate death over the idea of beauty, but he did say that his work always tried to unite the true with the beautiful; and when he had to choose one or the other, he usually chose the beautiful.

A few who believe in the relationship between beauty and the sciences say that if a theory is developed by a scientist with an exceptionally well-developed aesthetic sensibility, it can turn out to be true even if, at the time of its formulation, it appeared not to be so. Keats wrote that what the imagination seizes as beauty must be truth-whether it existed before or not. Heisenberg, in a discussion with Einstein, agreed with this principle. He says that if nature leads us to mathematical forms of great simplicity and beauty-by forms he is referring to coherent systems of hypothesis, axioms, etc.-to forms that no one has previously encountered, we cannot help thinking that they are "true", that they reveal a genuine feature of nature. When talking to Einstein, the two told of a feeling of almost frightening simplicity and wholeness of the relationships which nature suddenly spread out before them, and for which neither of them was in the least prepared.

Some have taken the relationship between science and beauty and given it a spiritual twist. J.W.P. Traphagan is one of them. He starts out by saying that he is very fascinated by the fact of beauty in the way the world is. He does not think our experience of beauty is

just emotional response, nor simply a matter of cultural determinacy. It is, rather concerned with a vital part of reality. And that reality is God. He feels that if God is the ultimate ground of everything, then God himself ties all these together. Our experience of beauty is really our sharing in the joy of his creation. He accommodates the laws of science, beauty, and religious experience by grounding them all in God. That way, everything is linked together through God.

All of these before-mentioned philosophers and physists have given very general descriptions of how beauty and the sciences (especially physics) relate. Weinberg explains that these descriptions have been put to use in the real world by scientists in both theorizing and experimenting. He does this by using the example of Einstein's theory of relativity. First, however, Weinberg warns that we not miss the point about the way the physicist uses beauty. When we say a physical theory is beautiful, we do not mean the same thing as when we say a rainbow or the sun is beautiful. It is much more like a horse breeder looking at a race horse and saying, "That's a beautiful horse." The race horse breeder is relying on a background of experience which is not formulated explicitly in terms of judgments that he can describe in logical terms. Yet on the basis of his experience in breeding race horses and seeing how well they do at the track, he knows that a particular horse has features which he cannot even name, which make it likely that that horse will win races.

Weinberg also clears up doubt about the appearance of these theories. He states that the first thing that must be said about what the physicist is looking for when he looks for beauty in a theory is that we are not talking about the mechanical beauty of equations on a page of paper. If you compare, for example, Newton's theory of gravitation with the more beautiful theory of Einstein's that replaced it, there really is not much to choose from in terms of just the appearance of the symbols on the piece of paper. Both theories consist of equations that tell you for a given distribution of matter, what is the gravitational field produced. There are only a few more equations in Einstein's theory. In fact, there was really only one piece of data that Einstein's theory succeeded in explaining that Had not been explained in Newton 's theory, and a number of pieces of data that were left unexplained. Still, Einstein wrote in a postcard to Arnold Sommerfield, "of the theory's general relativity, you will be convinced as soon as you see it." This is because Einstein's theory had a beauty of the type which is typical of beautiful theories. It rested on general principles, and these general principles required theory to have an especially unique structure. Einstein's theory had the same quality as a perfect painting or a perfect play, like a Greek tragedy. Looking at it, he could not imagine anything he would want to change.

These principles that determine the way that theories are developed are not to be thought of as mechanical principles that can

be exploited or applied in a perfectly straightforward and unthinking manner. Often as in the case of general relativity, the principles are formulated for the first time with the theory itself. They are often ambiguous. They are not principles like the axioms of geometry or arithmetic. They are general principles, more guidelines than concrete statements. One of the principles,for example, that is dealt with a good deal in the development of atomic physics in the early part of the 20th century is Niels Bohr's principle of complementarity, the principle that says that a physical system has very complementary aspects, and that you can learn about one of these aspects only at the cost of giving up full information about other aspects. As Gordon Mills said, this principle has more of the quality of the principle of literary criticism than a scientific principle. It is something which if we follow, we are led to beautiful theories.

Once the theories are in hand, Weinberg says that a sense of beauty can also be used to judge them, sometimes replacing experimentation. Many observers of science, and all working scientists know that scientists rely on a tremendous amount of guess work, inside philosophical preconceptions, and aesthetic judgments. Nevertheless, most people think that once a theory is formulated, however the scientist formulated it, whatever secret motives he had for developing his theory, the test of the theory would always be simply to have the theory be used to make predictions and then go

out to the laboratory and test the predictions. Weinberg says that is not entirely untrue, but it is not entirely true either. Experiments are remarkably expensive. A theory may be testable only in experiments that require investments of money that simply cannot be made unless the judgment is first made that the theory is a beautiful theory and worthy of being tested. The reason that the British went off to the South Pacific and the South Atlantic to test Einstein's theory was because the theory was a beautiful theory. It simply would not have been worthwhile testing it otherwise. Weinberg concedes that in the end, experiment can invalidate theories. It is terribly necessary to do experiments, not only to validate theories, but to suggest new theories. Still, the assessment of the validity of theories is by no means a matter of mechanically making predictions and then testing them.

Getting away from the experimenting in the sciences, Weinberg comments on the part of the sciences dealing only with mathematics. He says that this power of the sense of beauty in science is no better demonstrated than by mathematics. It is a commonplace that the sense of beauty drives mathematicians in what they do. Henri Poincare, a mathematician and physicist, said, "The most useful combinations of facts are precisely the most beautiful-I mean those that most charm this special sensibility which all mathematicians know, but of which laymen are so ignorant that they are often

tempted to smile at." G.H. Hardy, another mathematician, adds, "The mathematical patterns like painters and poets must be beautiful. The ideas like the colors of the work must fit together in a harmonious way. Beauty is the first test. There is no permanent place in the world for ugly mathematics. It may be hard to define mathematical beauty, but that is just as true of beauty of any kind." Now that makes a commonplace, that mathematicians are driven by their sense of beauty because after all, at least for a pure mathematician like Hardy, there is no outside goal; there is no goal outside mathematics itself that he is pursuing. He is pursuing only the goal of creating beautiful structures.

This goal of creating beautiful structures ultimately leads to one search in the sciences. That is the search for the laws of nature. Weinberg strongly suggests that if you keep asking a series of questions why ("Why is the sky blue?" Because particles scatter light in a certain way. "Why do particles interact that way with light?" Because the atoms are put together in a certain way. "Why are the atoms put together that way?" Because the particles inside the atom have certain properties. And so on.) you will come to an end ultimately, not in our lifetime, but ultimately you will come to an end and you will find a set of simple and beautiful principles. The principles are what we call the laws of nature. The beauty of our theories now is a link to learning the laws of nature. We think it is a

hint in anticipation, a premonition of the beauty of the laws of nature.

Yet on the other hand, the scientist is very human, is very far from perfect, and the struggle of the scientist to learn about nature is a struggle which has the same nobility that so much of human history does. It is human beings behaving in their confused way trying to get on with things. Weinberg adds that the history of science is perhaps the place where science and humanities truly can meet, and above all, the scientists in this effort to learn the underlying laws that govern the behavior of the universe are not behaving like an adding machine or according to some bureaucratic protocol, but are motivated as Plato in the Symposium said all human affairs are motivated, by a sense of beauty.

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